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BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

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TITLE

CASCADEL TREE SELECTION PLOT

A STUDY OF TREE SELECTION BY THE WESTERN PINE BEETLE

FINAL REPORT

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By
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Berkeley, California
April 10, 1942

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CASCADE TREE SELECTION PLOT

A STUDY OF TREE SELECTION BY THE WESTERN PINE BEETLE

FINAL REPORT

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CASCADEL TREE SELECTION PLOT
A STUDY OF TREE SELECTION BY THE WESTERN PINE BEETLE
FINAL REPORT

INTRODUCTION

The Cascadel tree selection plot is probably the oldest one in ponderosa pine on which long time studies of insect kill have been continued. It was established by the Forest Insect Division in 1926 when insect activity in the Cascadel area was on the increase. On this area records dating back to 1919 cover a total period of 22 years, during which insect aggression, principally of the western pine beetle, Dendroctonus brevicomis Lec., increased from low endemic to high epidemic and subsided again the low endemic conditions. Since it is now expected that the plot will be logged in the near future, it seems desirable to close the record and to analyze the results of this long term study.

The purpose of the plot was to study the selection habits of the western pine beetle in relation to (1) tree growth rate, (2) type of tree, and (3) endemic and epidemic conditions of infestation. The data were confined to these points in so far as it was possible from 1926 to 1941 during personnel changes, importance of other projects, and shortages in man power. The information obtained is now sufficient to justify certain conclusions of importance relating to the control of the western pine beetle.

LOCATION AND DESCRIPTION

This plot of 80 acres is 1 mile long by 1/8 mile wide. It is located in the central Sierra subregion near North Fork, California at 3,500 feet elevation. It includes parts of the northwest quarter of section 22 and southwest quarter of section 15, T 8 S, R 23 E. The long axis runs north and south. The plot traverses many draws and ridges, each having a variety of slopes, exposures, and growing conditions. The soil is mainly decomposed granite. Granite rock outcrops are frequent. The stand is predominantly ponderosa pine with an admixture of California black oak. Incense cedar are fairly common. Sugar pine, white fir, and Oregon ash occur in a few isolated spots in the bottoms of draws. The ground is covered by a dense growth of bear clover. Poison oak, chapparral brush, deer brush, and manzanita are well distributed. Growing conditions for ponderosa pine on the plot indicate that 75 percent (south) is Site III and 25 percent (north) is Site II. Growing conditions as a whole are typical of westside Sierra ponderosa pine lying between fringe and optimum type westside stands.

At the time the Cascadel plot was established each tree was described in as much detail as was considered of importance. The descriptions included diameter breast high (nearest even inch), total height, crown width and length, dominance, and conditions with regard to insects or disease.

The systems of crown classification now used (Dunning, Keen, Risk) were undeveloped and were never applied to more than a small portion of the plot in later years. No attempt was made to rate the relative health of individual trees. Insect losses were recorded in detail. An inventory was taken of both current and past losses dating back to 1919.

HISTORY

Previous to the time the plot was established, studies by Person (1926) of insect killed trees compared with living check trees growing in similar locations indicated that slow growing trees were preferred to those of fast growth in 75 percent of the cases. The data were based on 1,000 dead and 1,000 living check trees scattered over several areas in southern Oregon and northern California. The information clearly indicated a preference for trees of slow growth among trees compared individually under a variety of growing conditions. However, it was not possible to use the data for comparison with the stand as a whole in any given area or site quality. Data from intensive plot studies was therefore desirable to obtain a valid comparison of the growth rate of insect killed trees with that of the stand, and to judge the degree of tree selection over a long period under different conditions of infestation.

The initial growth data from the Cascadel plot (Person, 1929) showed a marked difference in annual ring width between insect killed and living trees. Comparisons in average ring width between 1,380 living and 16 to 56 dead trees showed that the ring width of dead trees was 1.25 millimeters less than that in the living trees. Data from 2 additional plots in northeastern California (Timber Mountain and Brown's Well) also showed that insect killed trees were growing slower than the average for the stand, although the difference was not great. From these data it was tentatively concluded : (1) that slower growing trees are preferred by the western pine beetle; (2) that there is a tendency to select trees having a certain low average growth rate; (3) that the degree of selection is highest in rapid growing stands and lowest in stands of low average growth rate; (4) that slow growing trees are preferred to fast growing trees within different diameter classes; and (5) that the degree of selection is strongly affected by the stage of infestation during endemic or epidemic conditions.

Insect activity, particularly by D. brevicomis and Ips confusus Lec., on the Cascadel plot and in surrounding timber had by 1931 reached an unprecedented high level. Although losses during the years immediately preceding were abnormally high, the figures for 1931 equalled the total for the 4 years previous. The suddenness and intensity of this epidemic has not been equalled since then in this Sierra subregion. The heaviest concentration of insects and kill on the plot was at the middle; losses were lightest at each end. Further detailed investigations of tree selection by growth rate during the epidemic were made and reported on (Struble, 1931). Although growth rate selection was still further substantiated by this study, the reasons for differences in concentration of infestations did not seem to be explained on the basis of growth rate selection alone.

Records from the plot were discontinued until 1940, when a complete inventory of all living and dead trees of the original stand was recorded and reported on (Struble, 1941). Trees which had grown from pole-size to merchantable timber were also measured and recorded. Growth data on the original stand were taken in 1941. Plans to log the Cascadel area were revealed by the Forest Service in August 1941, but actual cutting may be delayed for possibly one or more years.

EXTENT OF INSECT KILL 1919 TO 1940

Ponderosa pines killed by insects from 1919 to 1940 amounted to 22 percent of the total number and 28 percent of the total volume* on the Cascadel plot (Fig. 1). Over 50 percent of this loss occurred during the years from 1929 to 1934. Approximately 82 percent of the total volume was killed directly by the western pine beetle and 15 percent by a combination of Ips confusus and the western pine beetle. The remaining 3 percent was made up of flathead (Melanophila sp.) kills and unknown causes. Figures** are presented in Table 1 which follows.

Table 1. Distribution of Kill by Years

Year	Number of Trees	Volume (Board Feet)
1919	9	14,970
1920	2	1,180
1921	3	1,690
1922	6	5,540
1923	15	8,940
1924	3	1,460
1925	27	30,420
1926	9	4,800
1927	26	20,630
1928	3	03,820
1929	15	10,840
1930	24	21,030
1931	65	80,690
1932	42	42,060
1933	23	25,250
1934	17	10,720
1935	8	7,300
1936	10	13,390
1937	8	14,090
1938	2	7,400
1939	3	710
1940	2	3,530
Total	322 1/	329,460 2/

*The total stand, including living and insect-killed trees, at the time the Cascadel plot was established in 1926 amounted to 1470 trees having a volume of 1,169,410 board feet. These basic stand figures included all kill dating back to 1919.

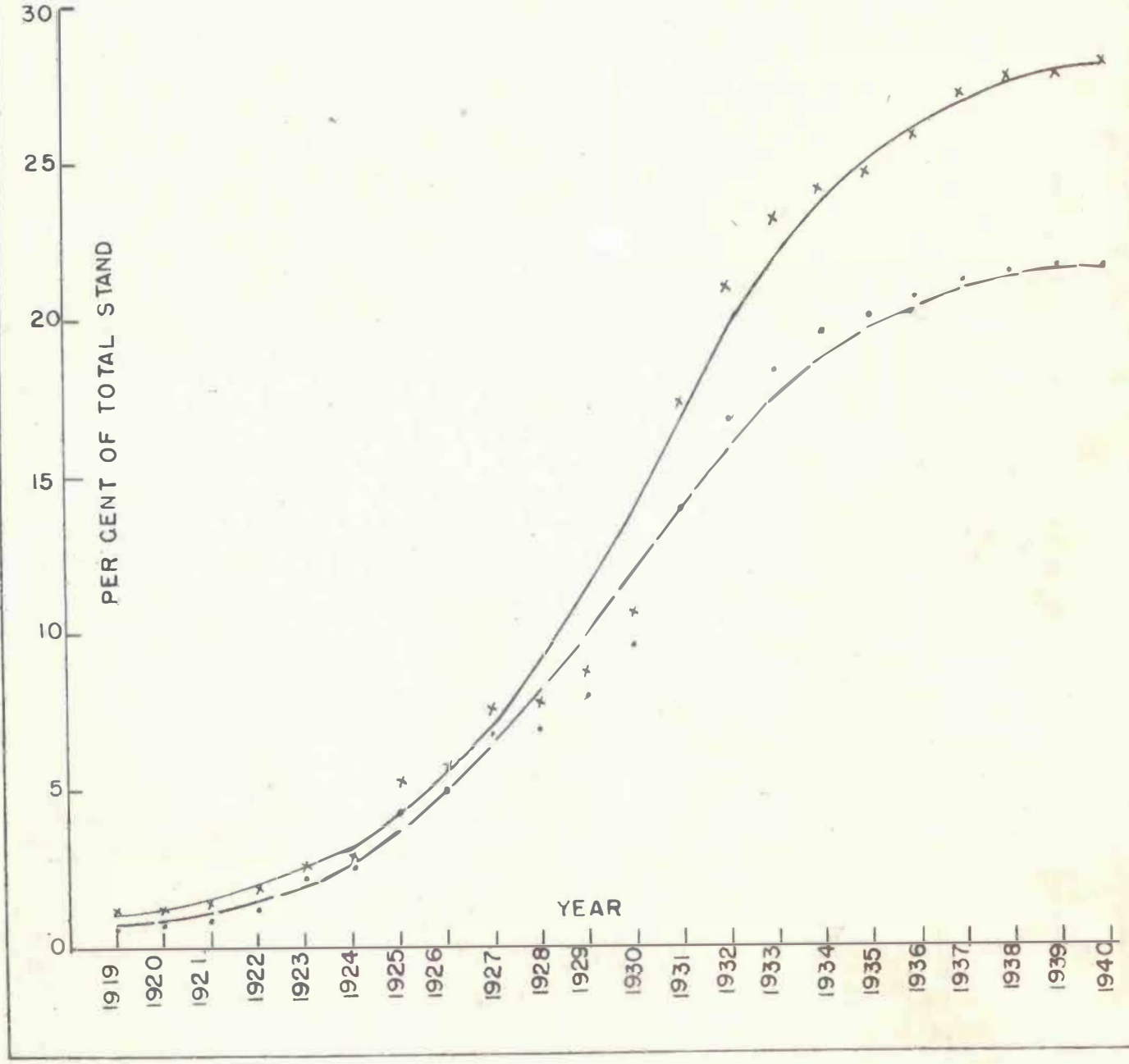
** The kill for each year from 1932 to 1937 is approximate since no records were taken from 1932-40. Trees dying since 1937 were accounted for accurately.

1/ ± 5 percent
2/ ± 2 percent

FIGURE 1.

CUMULATIVE LOSS CURVE IN PER CENT OF TOTAL STAND

VOLUME ×——— TREES .— —



TREE SELECTION BY INSECTS IN RELATION TO GROWTH RATE

The growth rate of trees during the period from 1917 to 1926 was used as a basis for determining the relation between growth rate and tree selection by insects in subsequent years. As may be seen in Table 2 and Figures 2 and 3, the selection for slower growing in preference to faster growing trees in comparison with the entire stand is beyond doubt.

Table 2. Distribution of Living and Insect Killed Trees by Growth Rate (1917 to 1926 average)

Growth Rate Millimeters 1917-1926	Number of Trees		Percent Died 1927-1940
	Living	Dead	
0.00-0.50	83	86	51
0.51-1.00	202	55	21
1.01-1.50	206	53	20
1.51-2.00	206	25	11
2.01-3.00	250	19	7
3.01-4.00	119	8	6
4.01-5.00	41	4	9
5.01-7.00	19	0	0
7.01-10.00	6	0	0
Totals	1,132	230	18

Among the trees selected by the western pine beetle, those growing .50 millimeters or less per year amounted to 37 percent of the total number killed and 6 percent of the total trees in the stand. Thirty-three percent of the trees growing 1.00 millimeters or less per year were killed. Moderate growing trees with annual rings 1.00 to 2.00 millimeters wide comprised 31 percent of the total number killed and 5 percent of the total trees in the stand. Fast-growing trees with rings wider than 2.00 millimeters per year comprised 12 percent of the total number killed and 2 percent of the total trees in the stand. Trees growing faster than 5 millimeters per year were unattacked. This data is conclusive evidence that slow growing trees are preferred to those of faster growth.

Person's analysis of growth rate selection for the Brown's Well (Modoc) plot in 1929 showed that 100 percent of the trees killed were growing 1.00 millimeter or less per year average, and that 90 percent were growing .40 millimeter or less per year. From this he formulated the tentative conclusion "that beetles prefer trees of very slow rate of growth, probably below 0.40 millimeters annual radial increase, as the average for any area." The Cascadel plot data show a much wider range in growth rate selection, even though there is a decided preference for slower growing trees. This difference in selection between Brown's Well and Cascadel may be expected because of the differences in growing conditions, precipitation, etc., between eastside and westside (Sierra) stands. An experimental marking, based on 0.40 millimeter or less annual radial growth per year set up by Person on 10 acres of the Cascadel plot in 1928 did not work out because there were very few trees growing this slowly. A marking plan based on 1.00 or less millimeters annual radial growth is probably more logical in westside areas.

FIGURE 2
DISTRIBUTION OF INSECT KILLED TREES BY GROWTH RATE IN PER CENT OF TOTAL NUMBER IN EACH GROWTH RATE GROUP

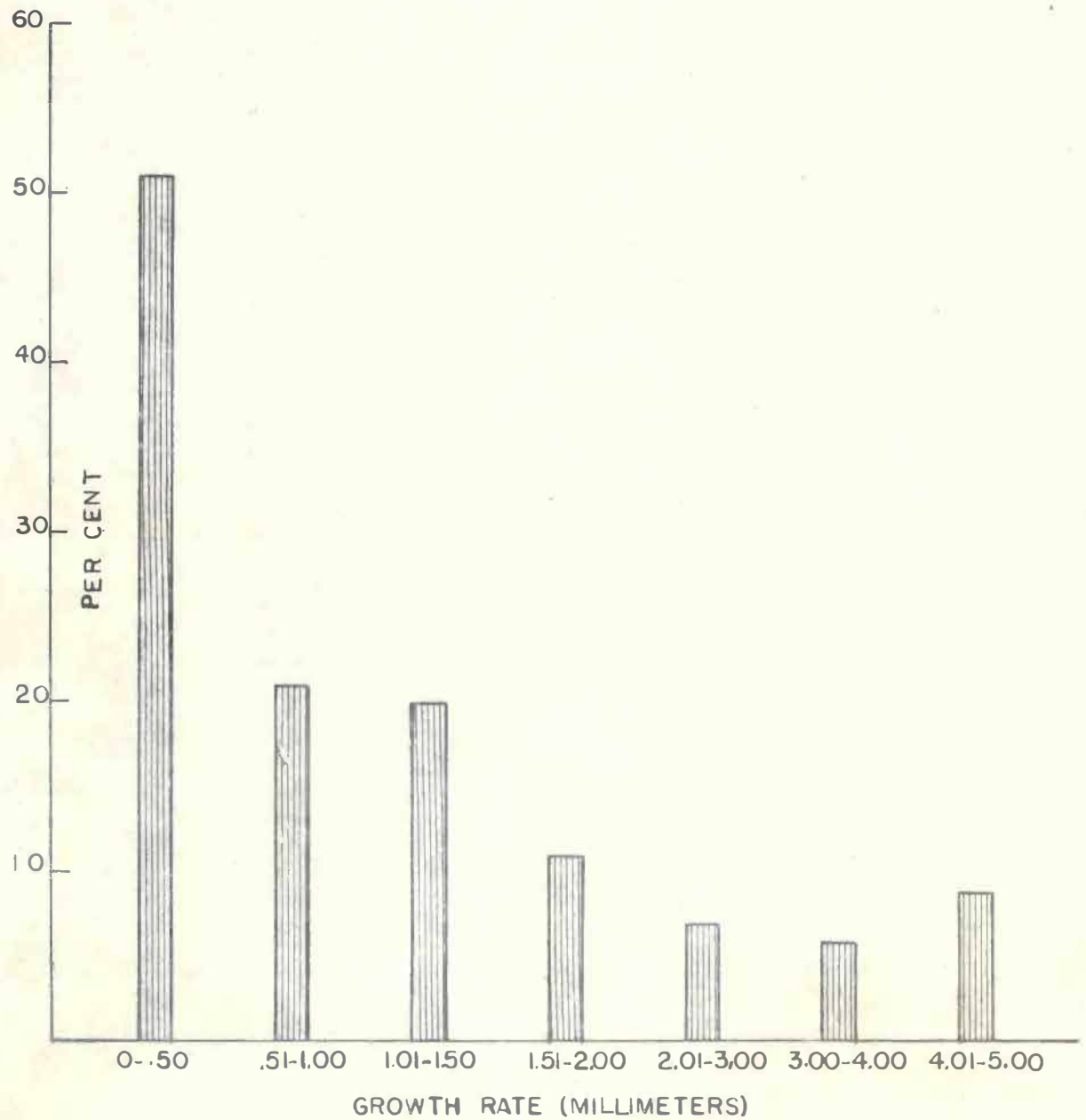
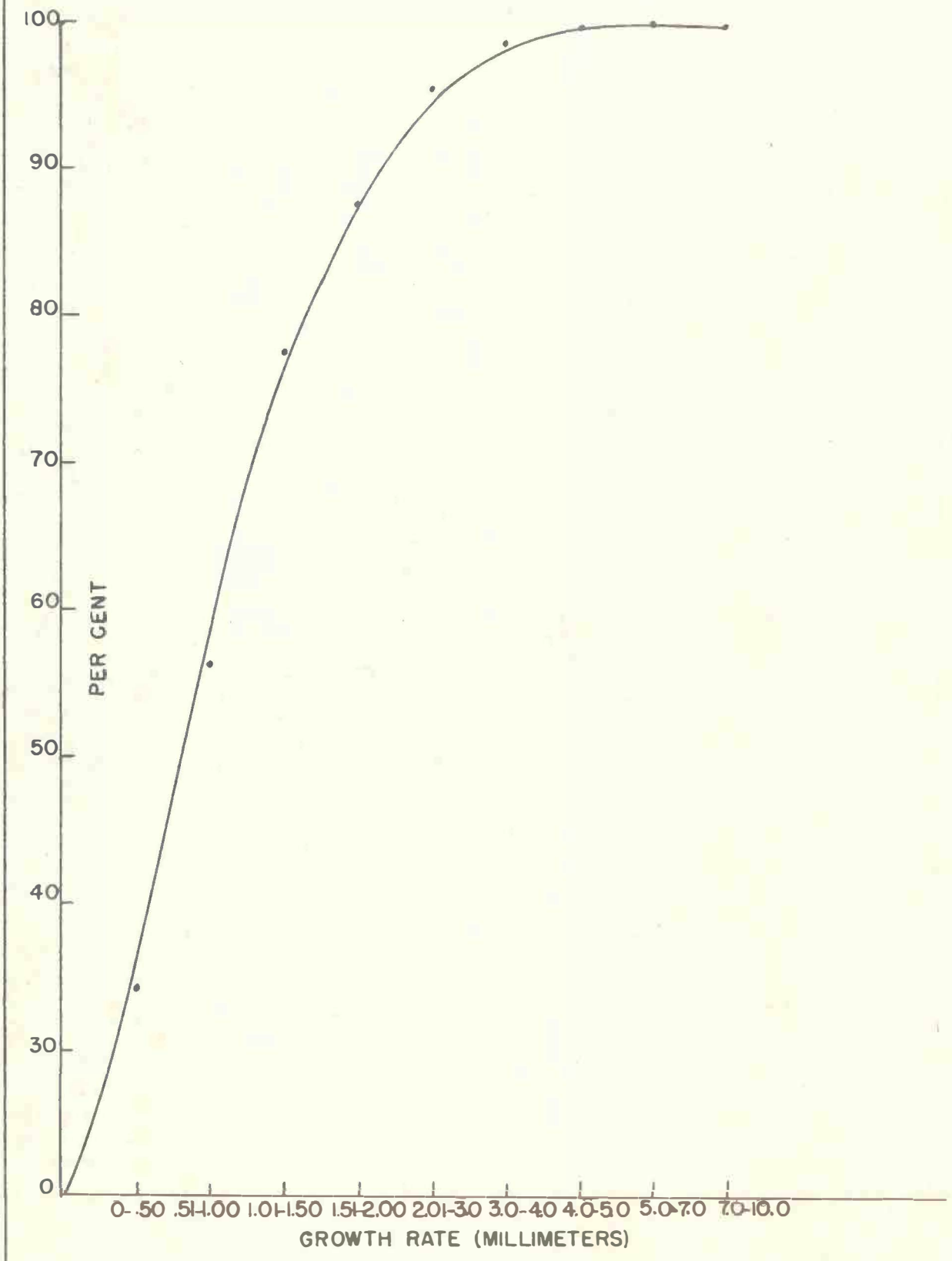


FIGURE 3
GROWTH RATE OF INSECT KILLED TREES
IN PER CENT OF TOTAL NUMBER KILLED



INFLUENCE OF EPIDEMIC ON GROWTH RATE SELECTION

The degree of tree selection was influenced considerably by differences in beetle activity during endemic and epidemic conditions. Both conditions prevailed during the period of study on the plot and the number of trees killed was sufficient to provide an interesting and significant comparison. Comparisons in the growth rate of trees killed during three periods, 1927-1929 (endemic), 1930-1934 (epidemic), and 1935-1940 (endemic), are shown by Figure 4. Three significant points are revealed which confirm certain past assumptions regarding growth rate selection during epidemics.

1. There was a distinct tendency during the epidemic for the beetle to attack faster growing trees. In fact, trees of medium growth were selected more often than those of slow growth. The average growth rate of all trees in this group (145) was 1.19 millimeters.

2. The trees selected before the epidemic were predominantly of slow growth. Only an occasional tree growing faster than 1.00 millimeter per year was killed. The average growth rate of trees in this group (21) was .80 millimeters.

3. During the post epidemic period the preference for slow growing trees was well marked, but there was still considerable activity among trees growing as fast as 3 millimeters per year. This is probably due to the increased populations immediately following the epidemic and to the lessened numbers of slow growing trees left to attack. The average growth rate of trees in this group (37) was .84 millimeters.

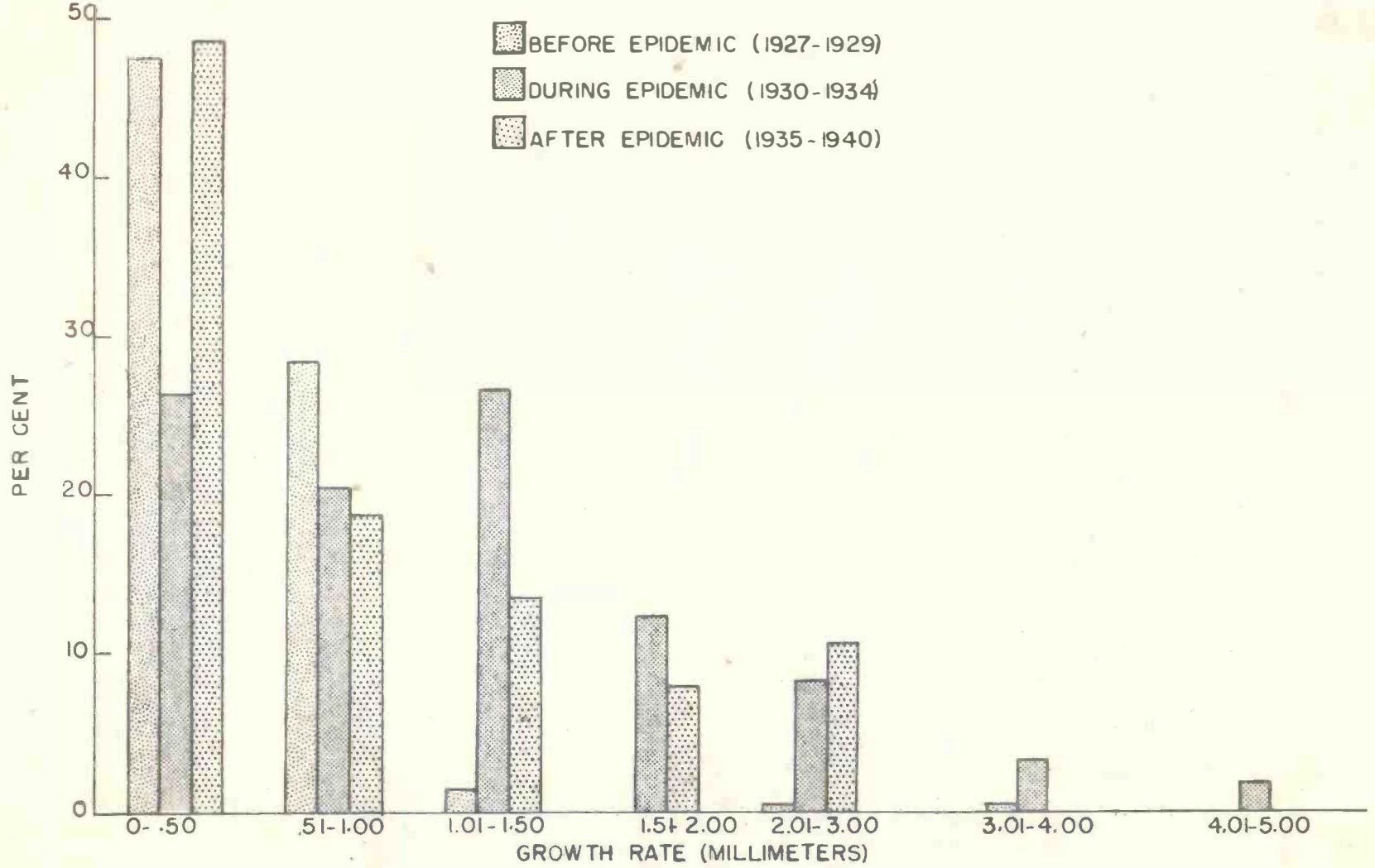
RELATION OF CURRENT GROWTH RATE TO RISE AND FALL OF INFESTATION

The average current growth rate of the stand apparently had a great deal of influence on the degree and condition of infestations on the Cascadel plot. Data from a 10 percent sample of living trees in the original stand taken in 1941 strongly indicated that previous epidemic and endemic conditions conformed to the growth pattern covering the years when these conditions were prevalent. A total number of 118 trees distributed evenly by diameter and location on the plot were used as a basis for the growth pattern (Figure 5). The growth curve for the years from 1923 to 1940 was used in this comparison. The significant points indicated are: (1) that the rapid decline in growth rate from 1929 to 1934 is in close correlation with the western pine beetle epidemic during this period; and (2) that the rapid rise in growth rate after 1934 is tied in with the relatively light kill of pines since then. The apparent relationship between growth trend and degree of infestation is in this case most probably more than a matter of coincidence.

It is to be noted from Table 1 that the actual decline in epidemic conditions had begun soon after the 1931 peak, and not after the increase in growth rate in 1934. This indicates that some factor in addition to increased growth rate was responsible for the decline, such as the pressure of populations or possibly a decrease in the number of susceptible trees. The factor of increased growth rate and vigor since 1934 doubtless was responsible for continued low endemic activity.

FIGURE 4

GROWTH RATE SELECTION BEFORE, DURING, AND AFTER EPIDEMIC IN PER CENT OF TOTAL INSECT KILLED TREES OCCURRING IN EACH GROWTH RATE GROUP FOR EACH PERIOD



TREE SELECTION IN RELATION TO DIAMETER

A study of tree selection in relation to diameter on the Cascadel plot, covering the period from 1926 to 1940 indicates that trees ranging from 24 to 34 inches d.b.h. are preferred, especially those ranging from 24 to 28 inches. In the 24 to 34 inch group the number of trees killed amounted to 9 percent of the total number of trees and 13 percent of the total volume in the stand. The kill among trees less than 24 inches amounted to 8 percent of the total number and 3 percent of the total volume; among trees over 36 inches d.b.h. the kill amounted to about 1.6 percent of the total number of trees and 7.3 percent of the total volume in the stand (Figures 6 and 7). From these data two logical conclusions are indicated: (1) that the selection of trees over 22 inches in diameter indicates a higher number of trees in these brackets; and (2) that trees under 24 inches d.b.h. may be considered to be thrifty and less susceptible to attacks in the majority of cases.

AMOUNT OF VOLUME LOST 1926 TO 1940

The board foot volume gained by the original stand still living in 1940 was considerably less than that killed by insects from 1926 to 1940. An estimate of the amount in terms of board feet, determined from the 10 percent sample mentioned previously and applied to the entire living original stand, amounted to 110,328 board feet.* The volume killed during the same period amounted to 269,460 board feet. The net loss was therefore 150,132 board feet, representing a net reduction of 13 percent of the original volume living in 1926.

The effect of insects during this period has been to deplete the stand. This was partially compensated for by the growth of poles into merchantable sized trees during this period. As mentioned in a report submitted by the writer in 1940, 403 new merchantable sized trees, having a volume of 58,670 board feet were recorded on the plot. As a result there are now actually 1,566 living merchantable sized trees on the plot or 177 more living merchantable sized trees than were present in 1926. The total 1940 volume, however, is 100,462 board feet less than it was in 1926. This volume loss may be largely compensated for by growth if the insect kill remains at its present low level for the next 10 years. On the other hand, another severe epidemic would most probably result in still further depletion.

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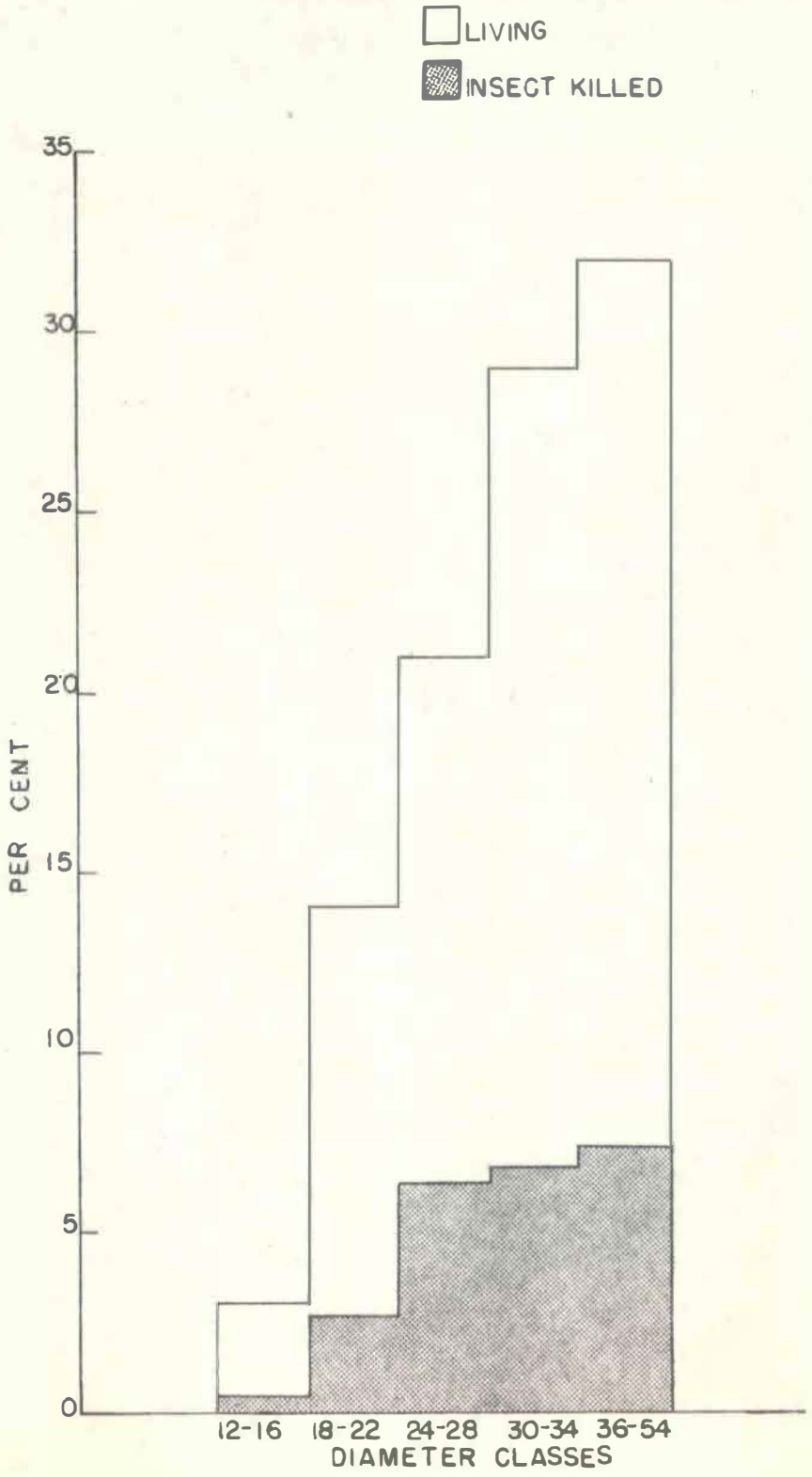
*The methods used in computing the increment in terms of volume (board measure) include the following steps:

1. Differences in diameter for the 14-year period were established by measurements of the total radial increment gain of each tree for the period in inches and subtracting twice this amount from the current diameter measurements.
2. The volume gained by each tree was determined from a plotted curve of volume over diameter.
3. The volume increment of each 4-inch diameter group represented a sample of the total living stand.
4. The volume increment of the total living stand was calculated by applying the volume increment of each 4-inch diameter group sample to the total number of trees occurring in the stand of each diameter group.

FIGURE 6
DISTRIBUTION OF LIVING AND INSECT KILLED TREES BY 4-INCH DIAMETER GROUPS IN PER CENT OF TOTAL STAND

FIGURE 7.
DISTRIBUTION OF LIVING AND INSECT KILLED VOLUME BY 4-INCH DIAMETER CLASSES IN PER CENT OF TOTAL VOLUME ON PLOT



TREE SELECTION IN RELATION TO CROWN TYPE

The relation between susceptibility and crown type on the Cascadel plot was indicated by Person (1929) through comparisons of crown length and width with beetle attacks. He found that trees with short narrow crowns were much more susceptible than trees with long, wide crowns, and concluded that "in general, the smaller the crown of a tree the greater its susceptibility to attack." Since Person's studies, no further data were continued on crown type and susceptibility at Cascadel or in other westside (Sierra) ponderosa pine stands.

DISCUSSION AND CONCLUSIONS

The Cascadel tree selection plot is probably about as typical of westside ponderosa pine stands as any in the central Sierras. The information obtained from it may be considered as applicable to any westside stands growing on similar sites where the annual precipitation is about the same. It is doubtful if any slight differences would affect the results of the study. The conclusions are therefore largely applicable to westside conditions. They are: (1) that the western pine beetle shows a distinct preference for slow growing trees; (2) that the degree of selection is dependent on both growth rate and stage of infestation, there being a much higher degree of sensitivity during endemic conditions than during epidemics; (3) that a tree is considered slow growing when the annual rings are 1.00 millimeter wide or less per year average for a 10-year period, and fast growing if the average width of annual rings for a 10-year period is more than 3.00 millimeters per year; (4) that trees growing faster than 5.00 millimeters average per year for a 10-year period are immune to attacks; (5) that a sudden lowering or rise in current average stand growth rate for a period of 2 years or longer may be subsequently followed by increased or decreased insect kill.

In westside pine stands the application of growth rate as a basis for determining whether a ponderosa pine is susceptible to attacks by the western pine beetle may be of practical value. Marking practice based on the number of annual rings in the last fourth inch of sapwood may adequately indicate whether a tree is susceptible or not. If, for example, there are 7 or more annual rings in this distance, the tree may be marked for cutting; if less than 7 annual rings the marking may be graded according to degree of susceptibility by ring width based on present information.

As indicated by the diameter study (Figures 6 and 7) greatest consideration should be given to trees 24 inches and above in diameter. In the groups with trees over 36 inches, a higher percentage of trees growing less than 1.00 millimeter per year average would be marked perhaps than in the 24 to 34 inch group because of the higher volumes involved. Relatively light marking of trees under 24 inches would be desired because of the small number of susceptible trees and volumes involved.

PROPOSALS FOR FURTHER STUDIES

The relation between crown type and susceptibility to the western pine beetle may be one of the most important phases of tree selection in westside ponderosa pine stands. Studies of this relationship on eastside stands within recent years have resulted in a high degree of success in lowering beetle activity through marking and removing high risk trees. The possibilities of a similar development in westside stands may prove to be a distinct advancement over present methods of control, even considering the physical difficulties involved on rough terrain.

Although the Cascadel plot is closed to further long time studies, there are still other areas of virgin ponderosa pine type just as typical on which a long range investigation of crown decadence and other factors in relation to insects may be continued. A proposal to establish a number of 20-acre plots in areas varying as to site, exposure, etc., is planned for the immediate future. On these plots marchantable sized trees will be classified according to degree of risk and according to Keen's and Dunning's crown classes. All trees that die as a result of insect attacks, subsequent to the establishment of plots, will be studied in the light of these classifications, and in addition, according to growth rate. All plots will be tied in with precipitation, soil moisture, and temperature records.

These plots will also provide an excellent opportunity to test out a marking plan based on growth rate as suggested. The coordination of factors of general crown condition, needle length, node length, etc., in addition to growth rate may serve as a more substantial basis for marking after a period of study.

SUMMARY

1. The Cascadel tree selection plot was established in 1926 for the purpose of studying the tree selection habits of the western pine beetle in a given stand of ponderosa pine representing average growing conditions in the central Sierra region. Preliminary data after 2 years of study on this plot and two others in northeastern California confirmed previous data, that slow growing trees were selected in preference to those of rapid growth.

2. The initial work of establishing the Cascadel plot, recording, compilation, and interpretation of data was undertaken by H. L. Person. Subsequent data taken intermittently from 1926 to 1940, during which endemic conditions rose rapidly to epidemic and again subsided to endemic conditions, has provided a strong basis for conclusions on growth rate selection.

3. The trees killed on the plot date back to 1919, giving a 22-year record of loss, from 1919 to 1940.

4. The total kill on the plot during this period amounted to 22 percent of the total number of originally recorded trees and 28 percent of the total volume. Over 50 percent of the kill occurred from 1929 to 1934.

5. Under endemic conditions on the plot (1918-1927), slow growing trees were selected by the western pine beetle in the greatest percentage of the cases; most of those killed were growing less than 1.00 mm per year in average radial increment for the 10-year period prior to death.

6. This preference was diminished during epidemic years (1930-1934) when there was a distinct tendency for the beetles to attack faster growing trees; moderately growing trees (average 1.19mm) were selected more often then the slower growing ones.

7. The return of endemic conditions (1935-1940) was accompanied also by a gradual return of selection preference for slower growing trees.

5. Preference of the western pine beetle for trees growing slower than 1.00 millimeter per year average for a 10-year period previous to death amounted to 33 percent of the total number of trees on the plot. Fifty-six percent of the total number of trees killed were in this slow growing group.

6. The degree of preference shown by the western pine beetle for slow growing trees is strongest before an epidemic and weakest at the peak.

7. Greater preference was shown by the beetle for trees ranging in diameter from 24 to 34 inches.

8. The preference of the beetle for slow growing trees may be of practical value in marking susceptible trees, particularly among those diameters having the greatest number of susceptible trees.

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FIGURE 1.

CUMULATIVE LOSS CURVE IN PER CENT OF TOTAL STAND

VOLUME ×——— TREES .— —

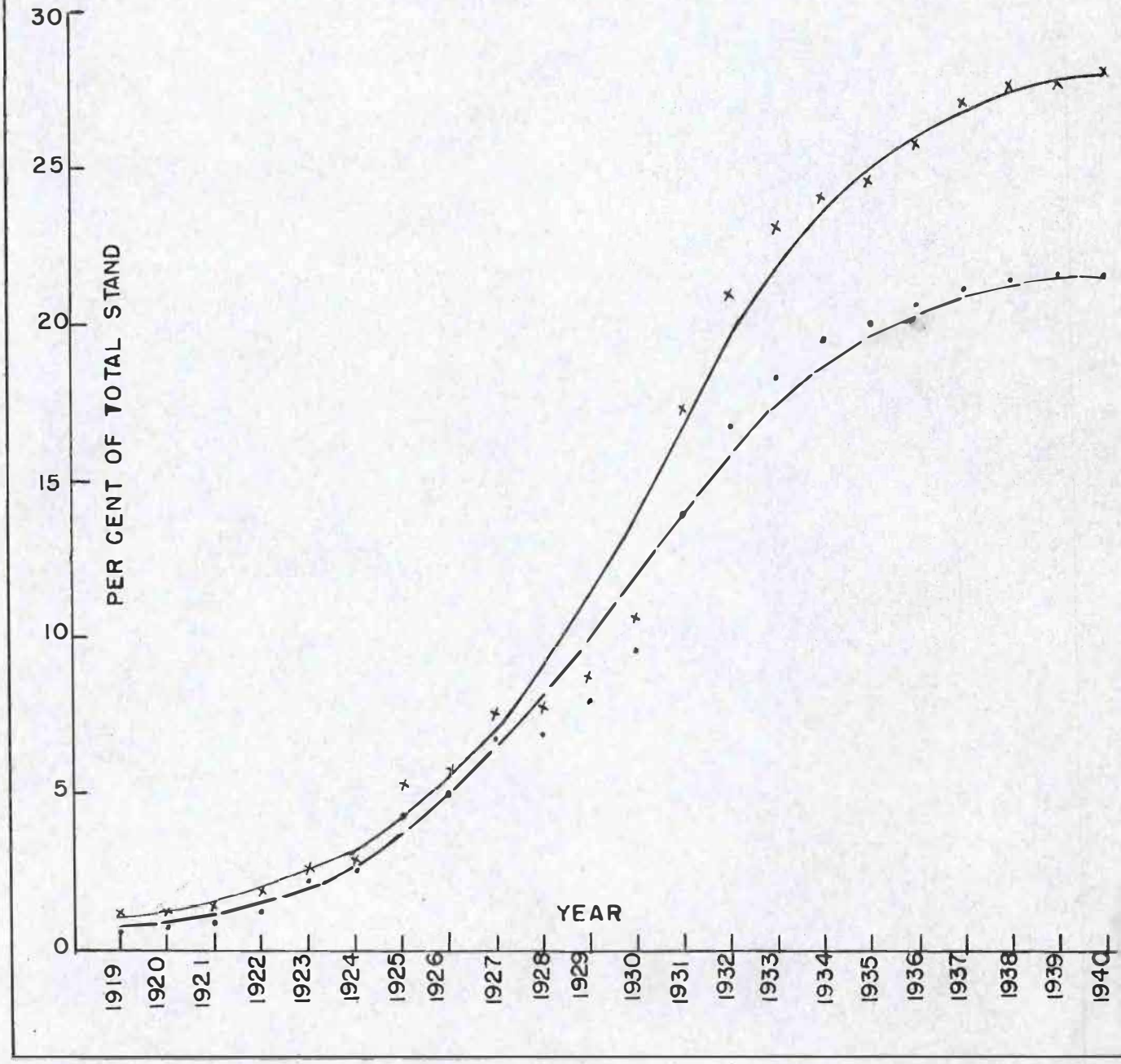

FIGURE 3

GROWTH RATE OF INSECT KILLED TREES
IN PER CENT OF TOTAL NUMBER KILLED

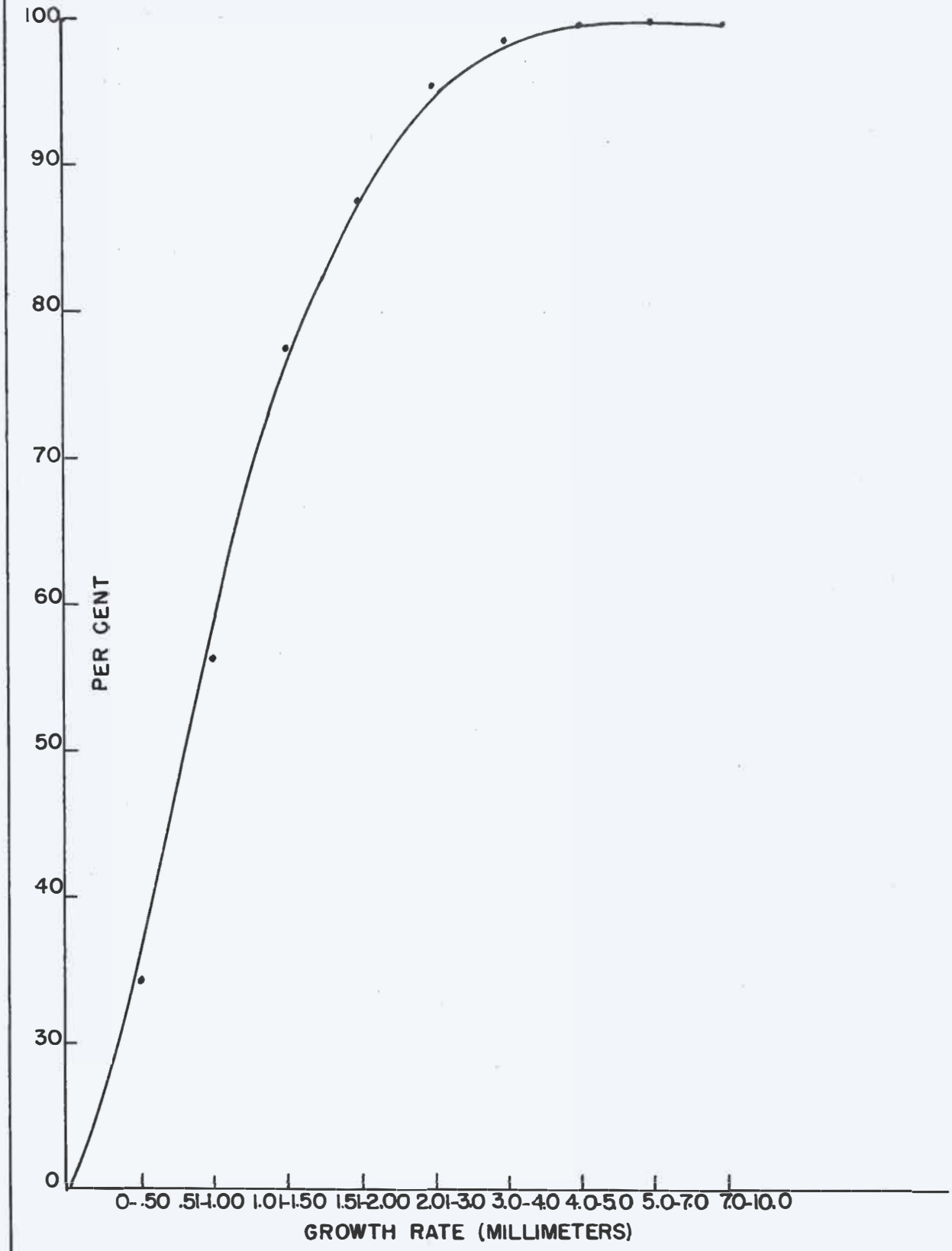

FIGURE 6
DISTRIBUTION OF LIVING AND INSECT KILLED TREES BY 4-INCH DIAMETER GROUPS IN PER CENT OF TOTAL STAND

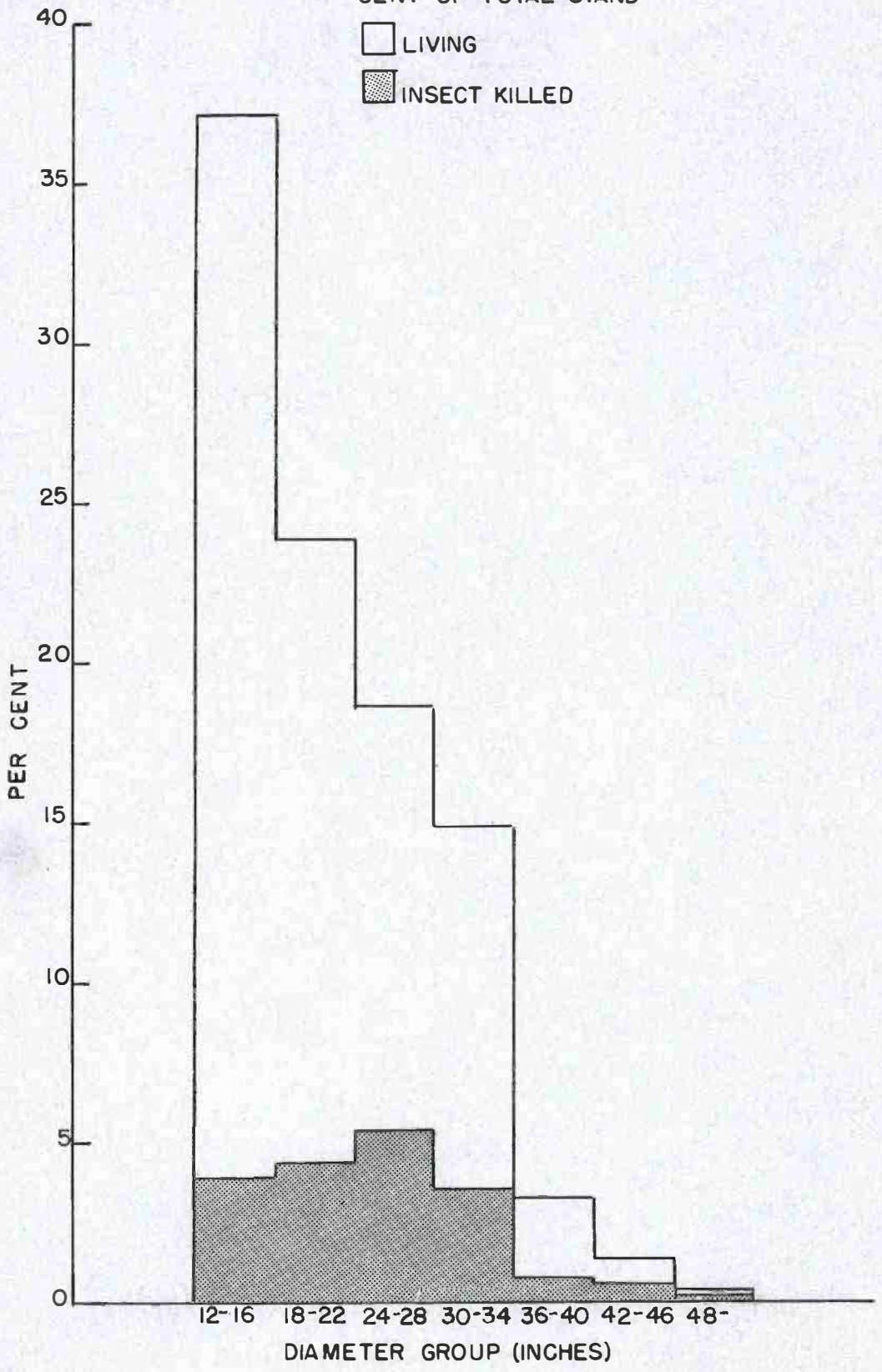

FIGURE 7.
DISTRIBUTION OF LIVING AND INSECT KILLED VOLUME BY 4-INCH DIAMETER CLASSES IN PER CENT OF TOTAL VOLUME ON PLOT

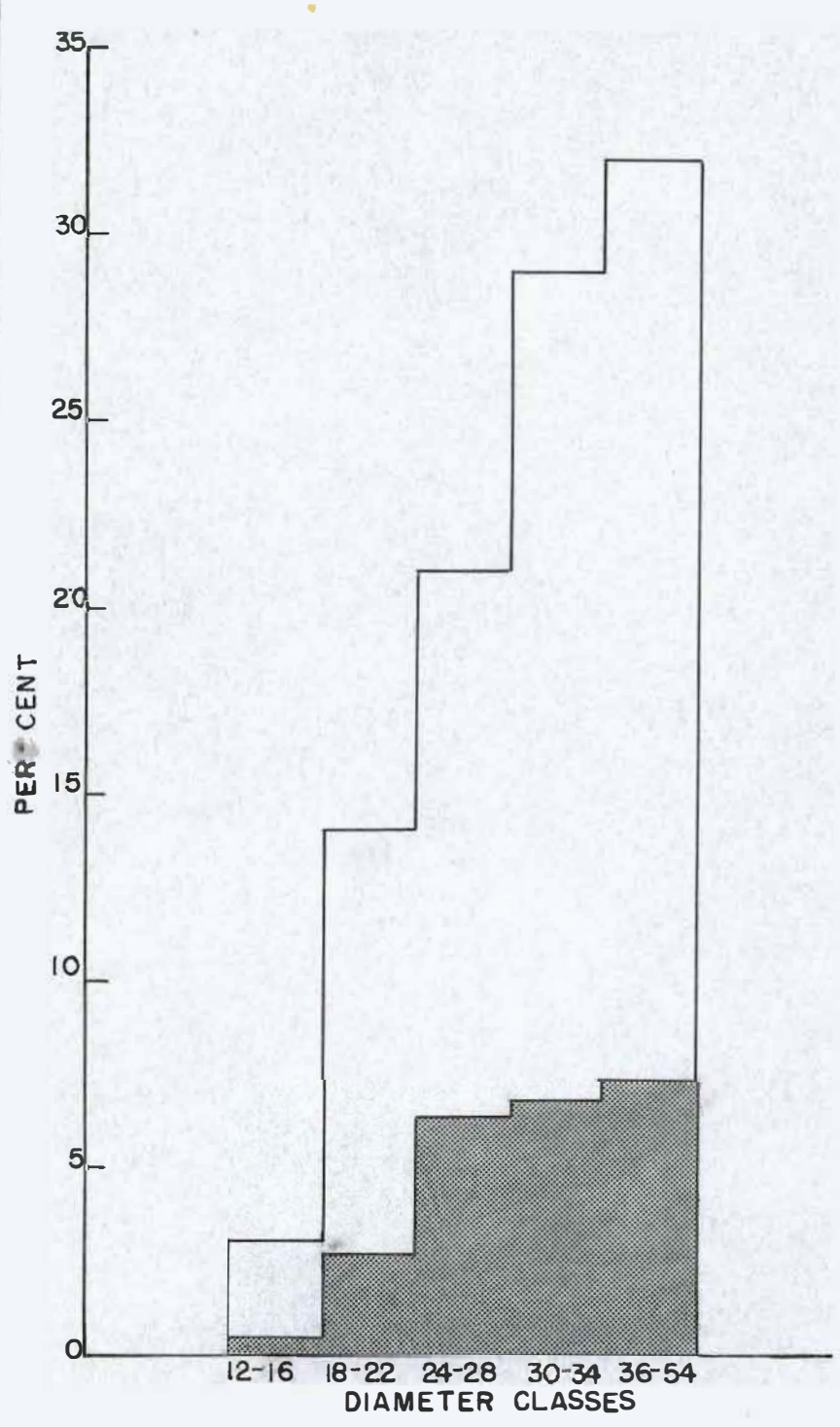

FIGURE 2
DISTRIBUTION OF INSECT KILLED TREES BY GROWTH RATE IN PER CENT OF TOTAL NUMBER IN EACH GROWTH RATE GROUP

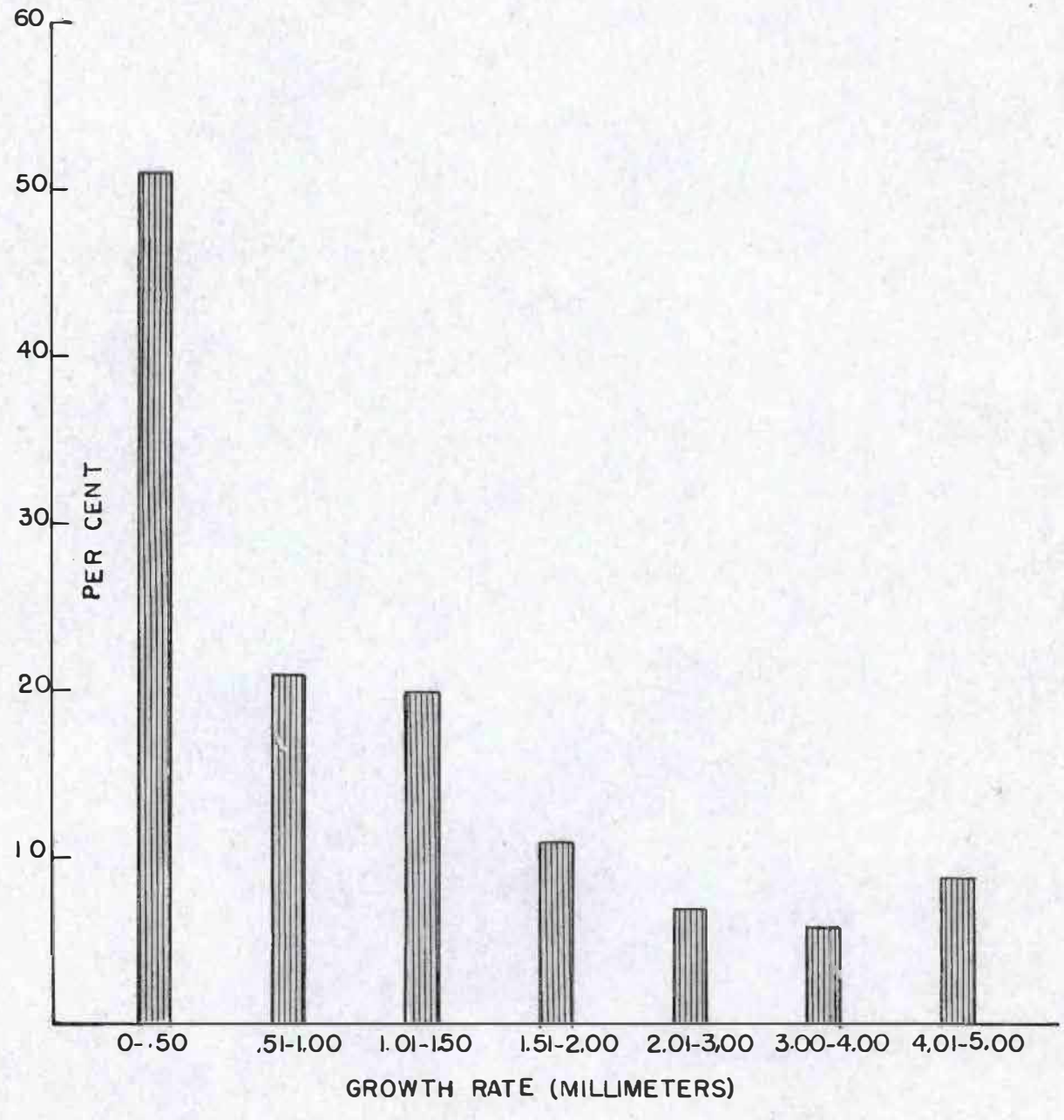

FIGURE 4

GROWTH RATE SELECTION BEFORE, DURING, AND AFTER EPIDEMIC IN PER CENT OF TOTAL INSECT KILLED TREES OCCURRING IN EACH GROWTH RATE GROUP FOR EACH PERIOD

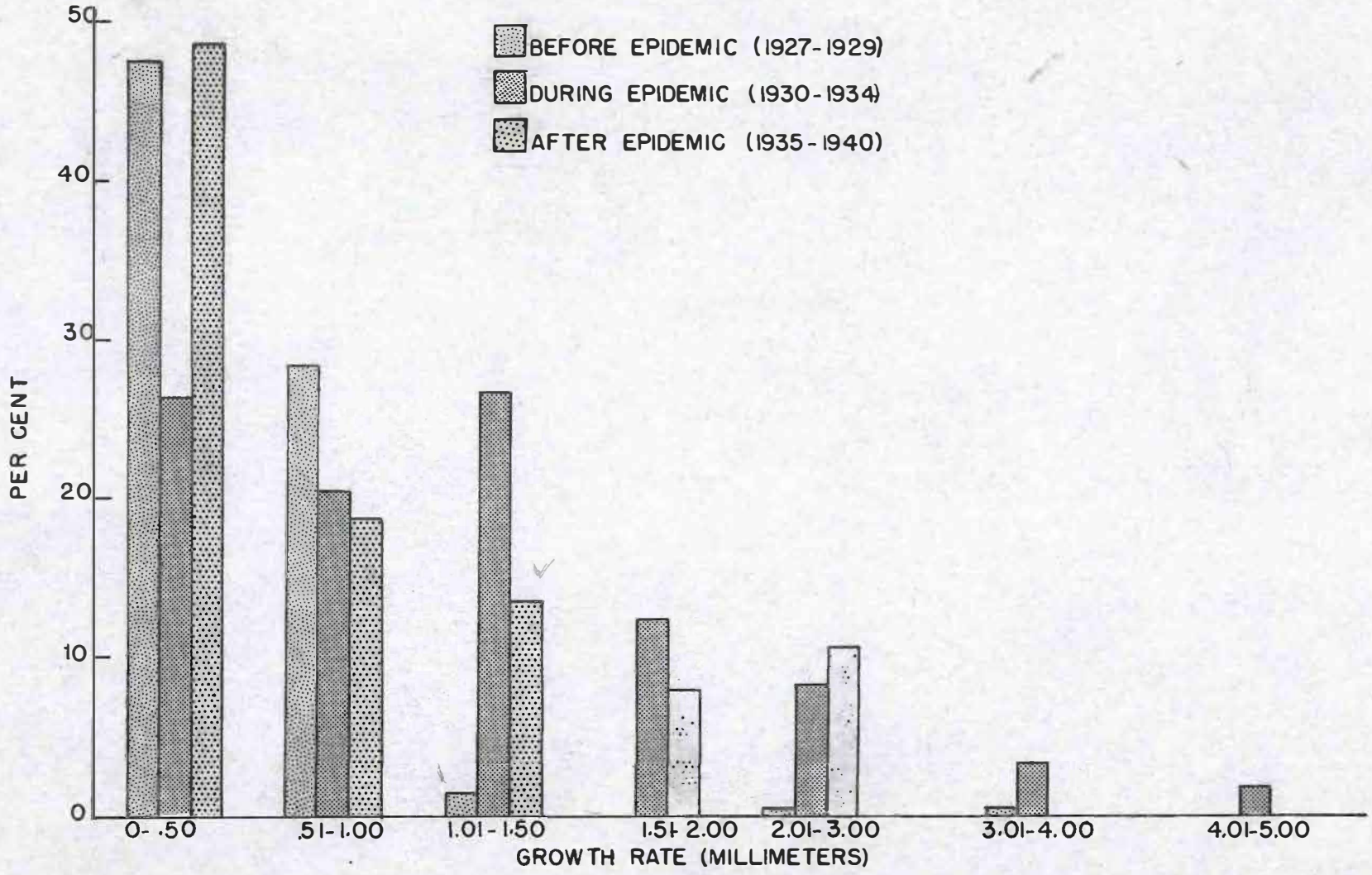

FIGURE I

AVERAGE GROWTH RATE OF 10 PER CENT SAMPLE OF ORIGINAL GREEN STAND FROM 1923 TO 1940 COMPARED WITH VOLUME OF TREES KILLED BY INSECTS DURING THIS PERIOD